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RESEARCH MEMORANDUM

POWER UNIT FOR HIGH-INTENSITY LIGHT SOURCE

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SUMMARY

A light-source power unit has been developed that provides reliable triggering, and easy synchronization with rotating elements or electric impulses. When used with conventional spark gaps and flash tubes, this power unit provides a light pulse of high intensity and short duration.

INTRODUCTION

The use of optical methods of flow visualization for supersonic flow research with rapidly changing transient conditions has brought about the need for a reliable light source of higher intensity and shorter duration than that obtainable with the sources in common use. In view of these requirements, a program of light-source development was initiated at the NACA Lewis laboratory to develop a source that would provide a high-intensity, short-duration light output for use in projector-type optical systems. Consideration of the various types of light source led to the choice of a high-voltage condenser discharge spark light source for this application because it inherently provides high intensity, small source size, and short duration.

The problems common to all condenser discharge spark supplies are those of finding a reliable means of initiating the discharge and maintaining a high impedance in the gap to provide a rapid rise in light intensity with efficient energy conversion into useful light output. The discharge may take place through a flash lamp or an exposed spark.

This report describes a power unit for providing pulses of energy to light sources and three light sources suitable for use with this power unit.

THEORY

The intensity of light produced in an open spark gap is a function of the energy dissipated in the gap and the volume in which this energy is dissipated. The portion of the available energy in the condensers that goes into the gap depends upon the ratio of gap resistance to total circuit resistance. Because the gap resistance is usually of the order of 1 ohm or less, it is of paramount importance to use discharge condensers of low series surge resistance and to minimize circuit resistance by the use of heavy conductors.

The values of inductance and capacitance in the discharge circuit determine whether the discharge will be oscillatory or an overdamped transient. The value of resistance for critical damping is $R_c = 2\sqrt{L/C}$, where R_c is the critical damping resistance in ohms, L is the total circuit inductance in henries, and C is the total circuit capacitance in farads. In circuits where the capacitance is large and wiring inductance is relatively small, the discharge is overdamped. Overdamping results in a gradual decay of light over a relatively long period. This long decay period may be reduced by the use of a high-voltage low-capacitance power source. In cases where wiring inductance is appreciable, as in cases where the spark gap is some distance removed from the condensers, the discharge will be oscillatory if the total series circuit resistance is less than that required for critical damping.

It has been found that the sudden application of a high-voltage pulse to a spark gap without the presence of any ionizing influence provides greater light output during the initial high-voltage phase of the discharge than is obtained when an ionizing trigger is used. The absence of an ionizing trigger permits the gap impedance to remain at a high value during the initial phase of the discharge with resulting increased circuit efficiency as more of the available energy is converted into light output in the gap. The light intensity from a spark may also be increased by providing greater pressure in the discharge path. This pressure increase may be accomplished by placing the entire gap assembly under pressure or by confining the discharge path, as is done in the Libessart type gap developed by General Paul Libessart of France.

A high-voltage low-capacity power source has been selected because of the short decay period. High over-voltage at the spark gap is obtained by charging the condensers in parallel and discharging in series.

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DESCRIPTION OF INSTRUMENT

The circuit is shown in figure 1. It consists of two discharge condensers C_1 and C_2, a type 5C22 hydrogen thyratron, a surge limiting inductance L, and two resistors R_c and R_d. The operation of the circuit is as follows: Condensers C_1 and C_2 are charged in parallel to a high voltage (10 to 15 kv) through the charging resistor R_c and the surge resistor R_d. When these condensers are fully charged, the discharge is initiated by applying a positive triggering pulse to the grid of the thyratron, which fires completing a circuit consisting of C_1, L, and the tube. The resulting oscillatory discharge reverses the polarity on C_1 after the first half cycle. At this time the polarities of the condensers are series additive, thus impressing nearly twice the supply voltage across the gap. This voltage pulse breaks down the gap and the two condensers discharge in series. Initiation of the spark discharge is reliable because the circuit action following the firing of the thyratron provides a voltage pulse on the gap well above the breakdown potential.

The type 5C22 hydrogen thyratron was chosen for this application because of its fast ionization and deionization times, wide temperature range of operation, and high surge current capabilities. Although the tube has a surge current rating of 325 amperes, currents as high as 2500 amperes have been passed without apparent damage or excess loss of tube life (reference 1). Its grid control characteristics make it particularly suitable for simple circuit configuration because no biasing is necessary to prevent conduction. The cathode of the thyratron and one side of the gap are at ground potential all the time, and the other side of the gap is at ground potential during the interval after the condensers are fully charged, until the trigger pulse is applied. The grounded output thus provided reduces the number of points that are at a high potential with respect to ground and increases the safety of operation. The inductance L is an air core coil of approximately 10 microhenries, which serves as a surge limiting choke to protect the thyratron.

The circuit is applicable to any size condensers, the limiting factor on size being the amount of energy that the thyratron can handle without damage. Three units have been constructed and operated satisfactorily using condensers of 0.05, 0.25, and 1.0 microfarads, charged to 15 kilovolts. The energy stored in the condensers of the three units is 11, 56, and 225 watt-seconds, respectively. The values of R_c and R_d are dependent on the current rating of the high-voltage power supply used to charge C_1 and C_2, higher values being necessary to protect the components in low-current power supplies. The charging rates of the condensers and the charging time interval that must be allowed between pulses are determined by both R_c and R_d because they are series charging resistors. In the supplies that were constructed, R_d had values of from 0.25 to 5.0 megohms. The resistor R_c was selected to limit the initial charging current to the surge current rating of the power supply rectifier. Both resistors must be capable of withstanding voltage surges of twice the peak rectifier voltage.

Synchronization of the spark discharge with rotating elements or electric impulses is easily accomplished because the time delay between trigger pulse and discharge is small and the jitter is negligible. A trigger pulse of 150-volt amplitude, 1-microsecond rise time, and 5-microsecond duration is recommended for the thyratron by the tube manufacturer and should produce a firing time delay of less than 1 microsecond and a jitter of about 0.04 microsecond. An additional time delay and jitter is introduced by the spark gap and connecting wiring. The total combined time delay is of the order of four microseconds with a jitter of less than one-half microsecond. The time delay due to the thyratron may be reduced to about one-half the values by the use of a triggering pulse of 200-volt amplitude and one-fourth microsecond rise time. Rotating elements may be synchronized by using any conventional method of providing a voltage pulse at some predetermined instant of angular rotation.

EVALUATION OF INSTRUMENT

Tests were conducted to determine the effective photographic intensity and duration of the light from various light sources used in combination with the power unit.

Method of evaluation. - Measurements of light pulse duration were made by two methods. The first method utilized a rotating mirror system, wherein a field of calibrated dots was focused on a film plate after having been reflected from the rotating mirror. The field was illuminated by the spark, which was synchronized with the mirror position so that, at the instant of discharge, the mirror was in a position that reflected the dots upon the film plate located several feet distant. The optical lever thus obtained gave an apparent movement on the film plate of 3/8 inch per microsecond when the mirror was rotating at 15,000 rpm. The effective photographic duration was determined by measuring the blur of the dots on the film plate.

The second method used a type 931A multiplier phototube, the output of which was fed into an oscilloscope and the resulting trace of the light wave form was photographed by an oscilloscope camera. The multiplier phototube was chosen because its output was not distorted by space charge effects within the tube.

Measurements of integrated intensity were made with an integrated intensity camera constructed at the Lewis laboratory; a schematic drawing of the camera is shown in figure 2. No absolute values were determined, all measurements being relative to the flash output of a standard high-pressure mercury vapor lamp that was used because of its universal application and wide acceptance. The image of the light source S was magnified and focused on a small aperature A that passed only a small fraction of the total source area. The light that passed through the aperture exposed a strip F on a roll of 35-millimeter film. An adjacent strip on the film was exposed by light from a calibrated lamp C passing through a variable-density element D. By a comparison of the exposure of the light-source strip with that of the variable-density strip, a relative exposure can be determined.

Results of evaluation. - The spark power units have been used with several types of spark gap as shown in figure 3. The sandwich gap consists of two 0.007- by 1/8-inch magnesium-ribbon electrodes sandwiched between two insulating plates of quartz or glass-bonded mica. The discharge is viewed edge on between the plates. In the Libessart gap, the discharge is confined to the small cylindrical volume between the electrodes, and the discharge is viewed end on through the small hole in the large electrode. The schlieren source is used in combination with an auxiliary steady light source to provide continuous illumination. The gap assembly is sealed and pressurized to provide greater intensity, and the spark discharge takes place in the center of the insulating insert that forms the aperture of the schlieren system. For taking flash pictures, the steady light source is turned off and the spark is discharged in the aperture. Standard flash tubes such as the helical FT-19 may also be pulsed with this power unit

Measurements of effective photographic duration and integrated intensity were made with the results listed in the following table. All intensity measurements are relative to the intensity of a standard high-pressure mercury vapor lamp when flashed with a source consisting of a 3-microfarad condenser charged to 2 kilovolts.

Light source	Input energy (watt-sec)	Integrated intensity (relative)	Duration (microsec)
High-pressure mercury-vapor flash	6	1	10-15
Sandwich gap[1]	11 225	0.5 5	0.2 4
Libessart gap[1]	11 225	15 30	3 8
Schlieren source[1]	56	2	1

[1]See figure 3.

The wave form of the light output from a sandwich gap using an 11 watt-second unit is shown in figure 4. The rise time of the light output is seen to be less than 0.05 microsecond to peak intensity. The succeeding oscillations that follow the initial pulse may be reduced by the addition of a small damping resistance in series with the discharge. There is, of course, some reduction in intensity due to the losses in the resistor; however, the intensity is still adequate for photography.

CONCLUDING REMARKS

A power unit for a high-intensity light source has been developed which provides light pulses of short duration for the photography of high-speed air flow. The unit when used with conventional spark gaps and flash tubes may be easily synchronized with rotating elements or electric impulses.

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REFERENCE

1. Whelan, W. T.: Recent Research on Pulsed Light Sources. Trans. AIEE, vol. 67, 1948, pp. 1303-1307.

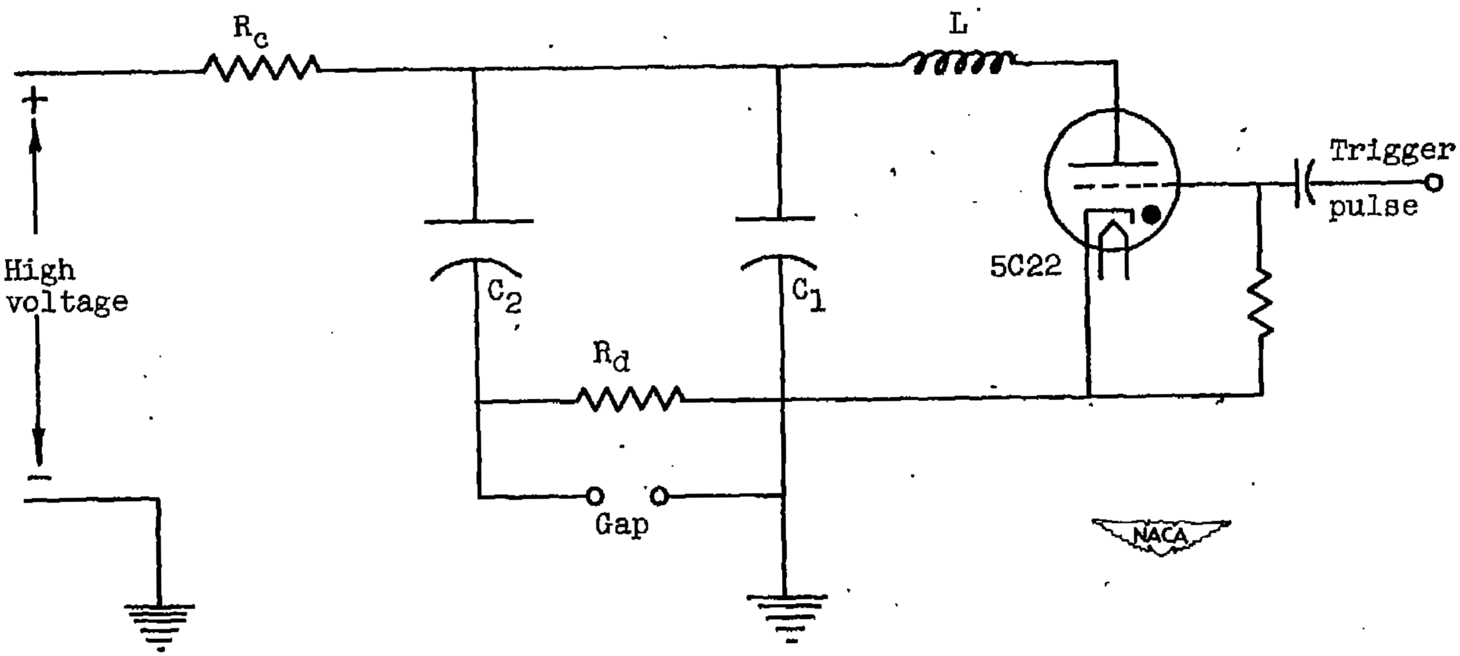

Figure 1. - Schematic wiring diagram of power unit.

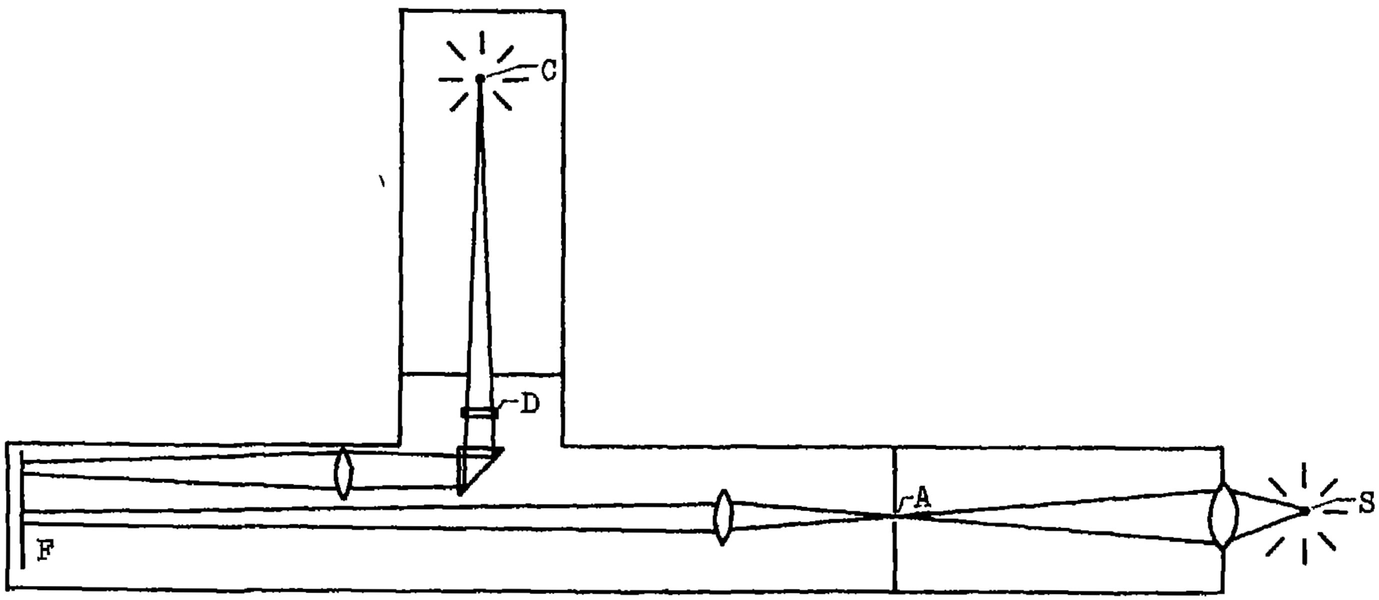

Figure 2. - Sketch of integrated-intensity camera.

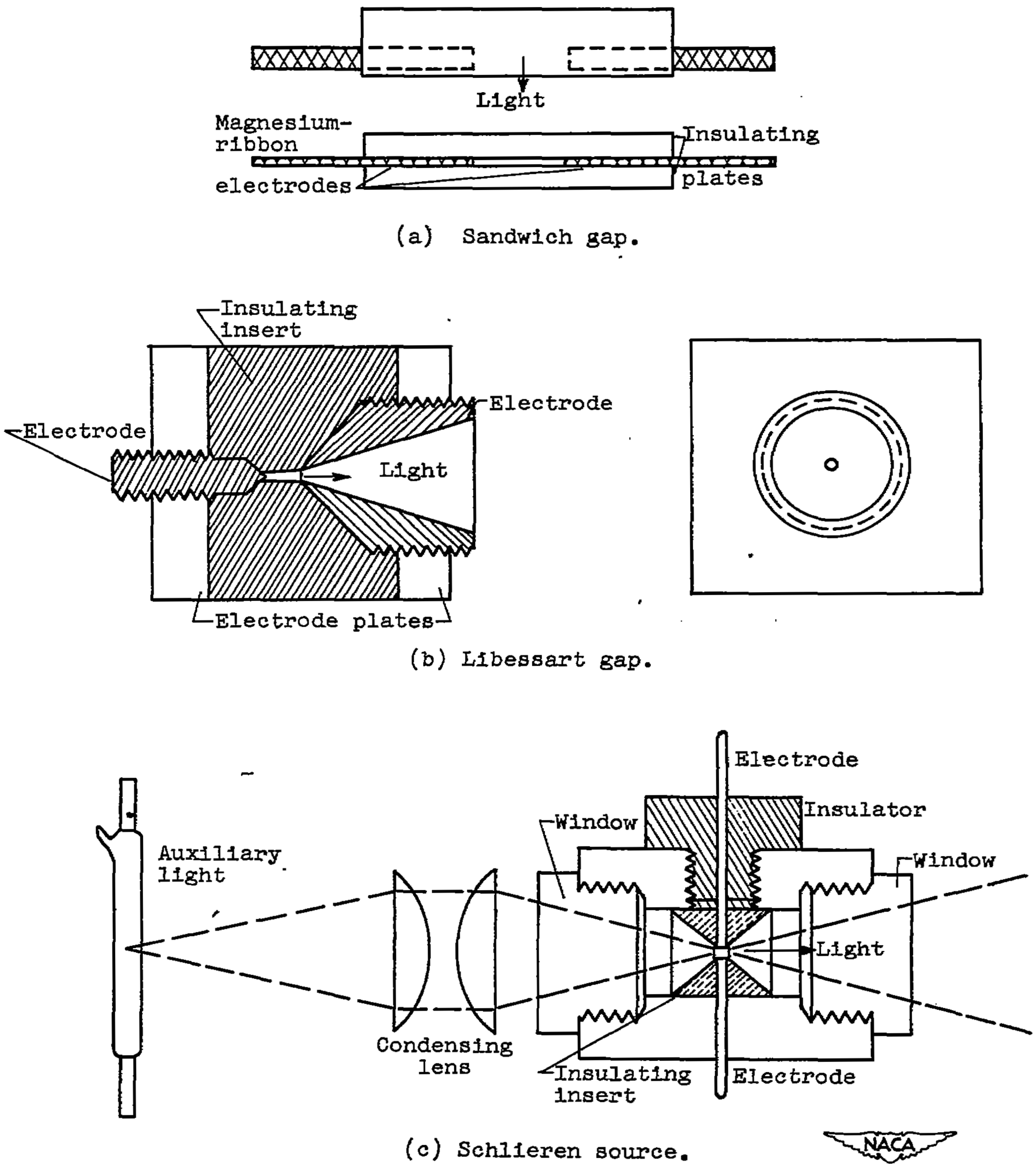

Figure 3. - Sketches of several types of light source.

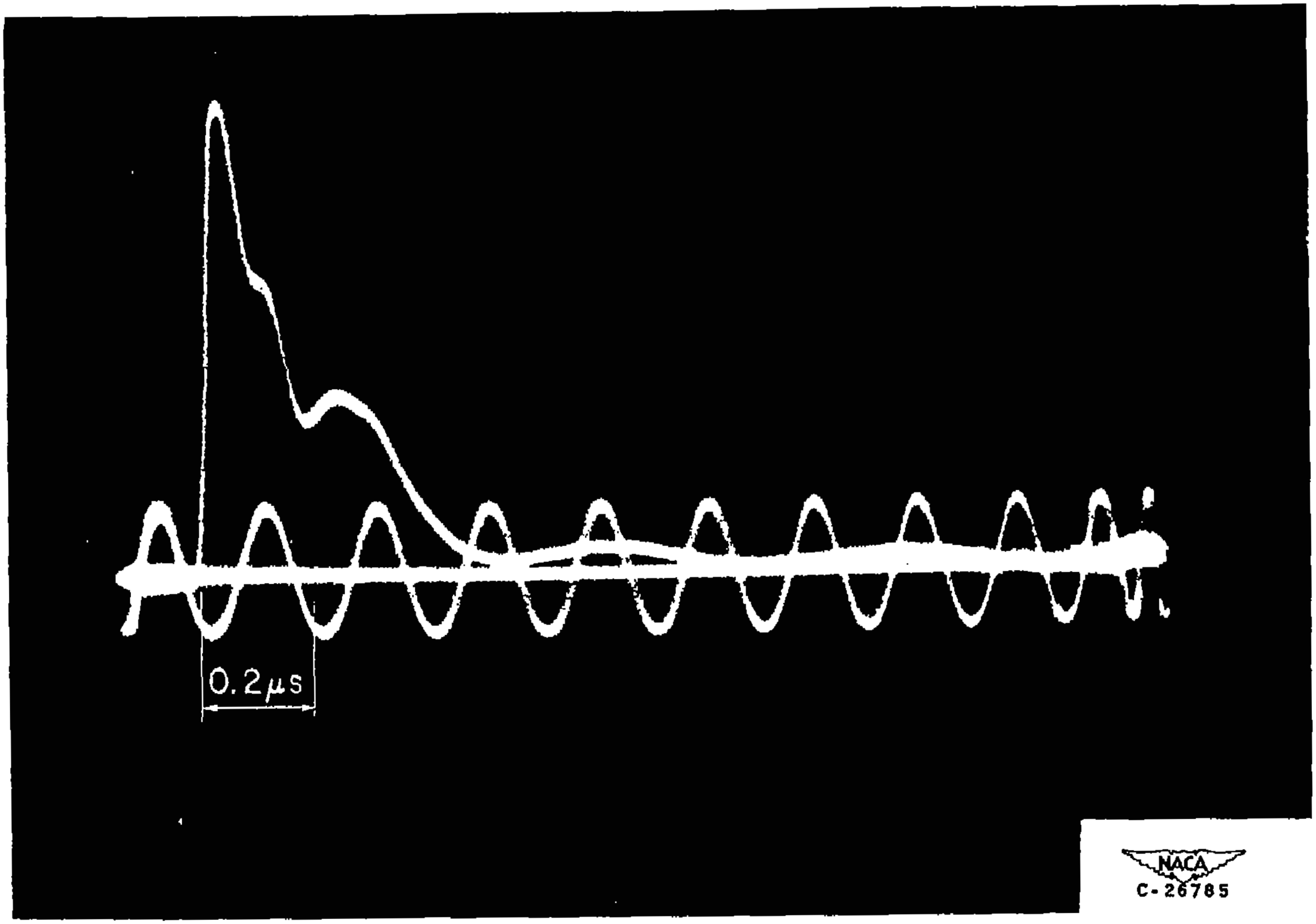

Figure 4. - Oscilloscope record of light-output wave form. Sandwich gap; electrode spacing, 3/8 inch; condenser size, 0.05 microfarad; charging voltage, 11,500 volts; calibration sine wave, 1 cycle = 0.2 microsecond.